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Approaching historic reindeer herding in northern Sweden by stable isotope analysis

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A strong cultural connection exists between reindeer and modern Sámi identity and economy. Reindeer domestication is, however, a rather late event, and there are many Sámi who live off resources other than reindeer herding. The use of stable isotope analysis on historic reindeer from different geographic areas can contribute to analysing both the processes involved in reindeer domestication and different environmental utilization by the Sámi. In this study, reindeer bones from six different sites in northern Sweden, ranging in date from the 11th to the 20th century, were analysed for stable isotopes to study how reindeer have been utilized in various historic contexts – settlements, offering sites and a marketplace. The stable isotope analysis demonstrated different practices in utilization of reindeer, such as foddering. Foddering is suggested to have caused the elevated $\delta^{15}N$ values found in reindeer at the offering sites Vindelgransele and Unna Saiva, as well as at the settlement Vivallen. The analysis further indicates that the offering sites were used by single Sámi groups. An important outcome of our study is that the biology of reindeer in Sápmi was culturally influenced by the Sámi even before the reindeer was domesticated.

Keywords: reindeer pastoralism, stable isotope analysis, carbon, nitrogen, sulphur, bone collagen, Sámi cultures, northern Sweden, diet, mobility

Introduction

The reindeer is important both for subsistence and to the cultural identity of indigenous groups living in circumpolar areas, such as the Sámi in northern Fennoscandia. Reindeer antler and bone deposits are among the most frequent finds at Sámi offering sites, compared to other faunal remains (Manker 1957:52). The offering of reindeer was made to get a successful hunt and/or successful reindeer herding (Mebius 2003:148–153). The reindeer was also an important food source, not only the meat but also the milk. Reindeer also provided raw material for clothing and artefacts and were important for transportation.

The reindeer is ecologically classified as a grazer with a diet varying according to season. During the winter the diet is mainly based on lichens, whereas the diet during the summer is based on more protein-rich herbs, shrubs and grasses (Vorren & Manker 1976:32; Mårell 2006:7; Morris et al. 2018). Today, there are two different subspecies of wild reindeer in Fennoscandia, the forest (or woodland) reindeer (Rangifer tarandus ssp. fennicus) and the mountain (or tundra) reindeer (Rangifer tarandus ssp. tarandus) (Mattioli 2011; Røed et al. 2011). Both wild subspecies are now less common but have to be taken into consideration as more prominent in prehistoric and historic periods. The differences between them are mainly migration range and gregariousness, where the forest reindeer are less gregarious and undertake shorter seasonal migrations compared to the mountain reindeer (Ingold 1980:18).

Today, the dominant reindeer in Fennoscandia is the domesticated reindeer. When reindeer pastoralism first occurred in Fennoscandia is still very much debated. While some researchers argue that pastoralism was introduced as early as the first millennium AD (Aronsson 1991; Hedman 2003; Bergman et al. 2008; Andersen 2011), others claim that it developed between the 14th and the 17th centuries (Vorren 1980; Lundmark 1982; Mulk 1994; Wallerström 2000; Hansen & Olsen 2006; Sommerseth 2009; 2011). Bjørnstad et al. (2012) performed aDNA analysis on prehistoric and historic reindeer from eastern Finnmark in Norway to suggest that the timing of domestication was no earlier than the Middle Ages, as the domesticated reindeer haplotype is lacking from reindeer dated to the Stone Age and Iron Age. Interdisciplinary research using aDNA analysis on reindeer populations, ranging from northern Scandinavia to Russia, resulted in a discussion of two different origins for reindeer domestication, one in Fennoscandia and one in Russia (Røed et al. 2008; 2011; Weldenegodguad et al. 2020). It was further suggested that the mountain reindeer was the subspecies that was domesticated, owing to their more pronounced gregarious behaviour and their sophisticated social organization.

Besides the two subspecies (genotypes), there are also a number of reindeer ecotypes, of which two exist in Fennoscandia, the mountain and the forest ecotypes. Although the genotype and the ecotype can overlap, this is not necessarily always the case (Mallory & Hillis 1998).

To provide an understanding of how reindeer have been utilized in various historic contexts, we have analysed reindeer bones using stable isotope analysis, from six historic sites in northern Sweden – settlements, offering sites and a marketplace. Our basic assumptions are that (1) different types of environment and diet result in different isotopic values, (2) different types of sites result in different variation in isotopic values, and (3) the variation provides information on whether or not all the reindeer came from a homogenous population, from one site, from a similar environment and/or have been herded in a similar way.

Reindeer herding and domestication

According to the Oxford Dictionary of Zoology, domestication is defined as 'The selective breeding of species by humans in order to accommodate human needs. Domestication also requires considerable modification of natural ecosystems to ensure the survival of, and optimum production from, the domesticated species' (Allaby 2014). Domesticated reindeer are sometimes defined as semi-domesticated, since the herding of reindeer has less ecological impact than traditional animal husbandry (e.g. Suominen & Olofsson 2000).

According to Phebe Fjellström, two types of reindeer herding subsistence were traditionally practiced in Sweden, by forest Sámi and mountain Sámi, respectively (Fjellström 1985:149ff). These two herding groups have slightly different economic and social organizations. Mountain Sámi move over large areas, from one ecological zone to another, whereas forest Sámi keep their reindeer more or less in the same ecological zone, in forest areas with good pasture (Hedman 2003; Andersen 2011). From the early Iron Age, traces of the forest Sámi are visible through the appearance of new settlement patterns in forest areas (Hedman 2003:18). In contrast to the mountain Sámi, the forest Sámi kept smaller reindeer herds in combination with fishing and hunting (Khazanov 1984). The forest Sámi also bred the reindeer for transport and to use as decoys in the hunt for wild reindeer (Vorren & Manker 1976:111ff). Just as Sámi in Sweden move their reindeer to the high mountain areas in the summer, mountain Sámi in Norway move with their reindeers to islands off the Norwegian coast during the summer.

Besides being a source of meat, tame reindeer have been important for transportation and communication (Bjørklund 2013). The question of when the domestication of reindeer took place is therefore of great interest. The earliest written source supporting the idea of early reindeer domestication dates to the 9th century AD, and it describes how the Norse chieftain Ottar visits King Alfred the Great in England. The text mentions that Ottar had 600 unsold reindeer, of which six were tame (although not necessarily domesticated).

Arell (1977:23, 249) used court records from the Swedish colonization period, AD 1660–1870, to argue that reindeer domestication became more intensive as fishing and hunting decreased. A decrease in finds of fish bones and an increase of reindeer bones between the 14th and the 17th centuries could indicate of a period of intensified reindeer domestication (Karlsson 2006:91). This is supported by a few ^{14}C dates from the offering site Unna Saiva, pointing to reindeer herding in the 12th–13th centuries, in the vicinity of Gällivare (Salmi et al. 2015). The late Iron Age and especially the Middle Ages are periods of a multicultural landscape and inter-cultural relationships in Sápmi (Bergman 2010:187; Bergman & Edlund 2016).

To summarize, some researchers argue that reindeer domestication started before the Middle Ages (Aronsson 1991), whereas others argue that it started during the Middle Ages, slightly before the Reforma-

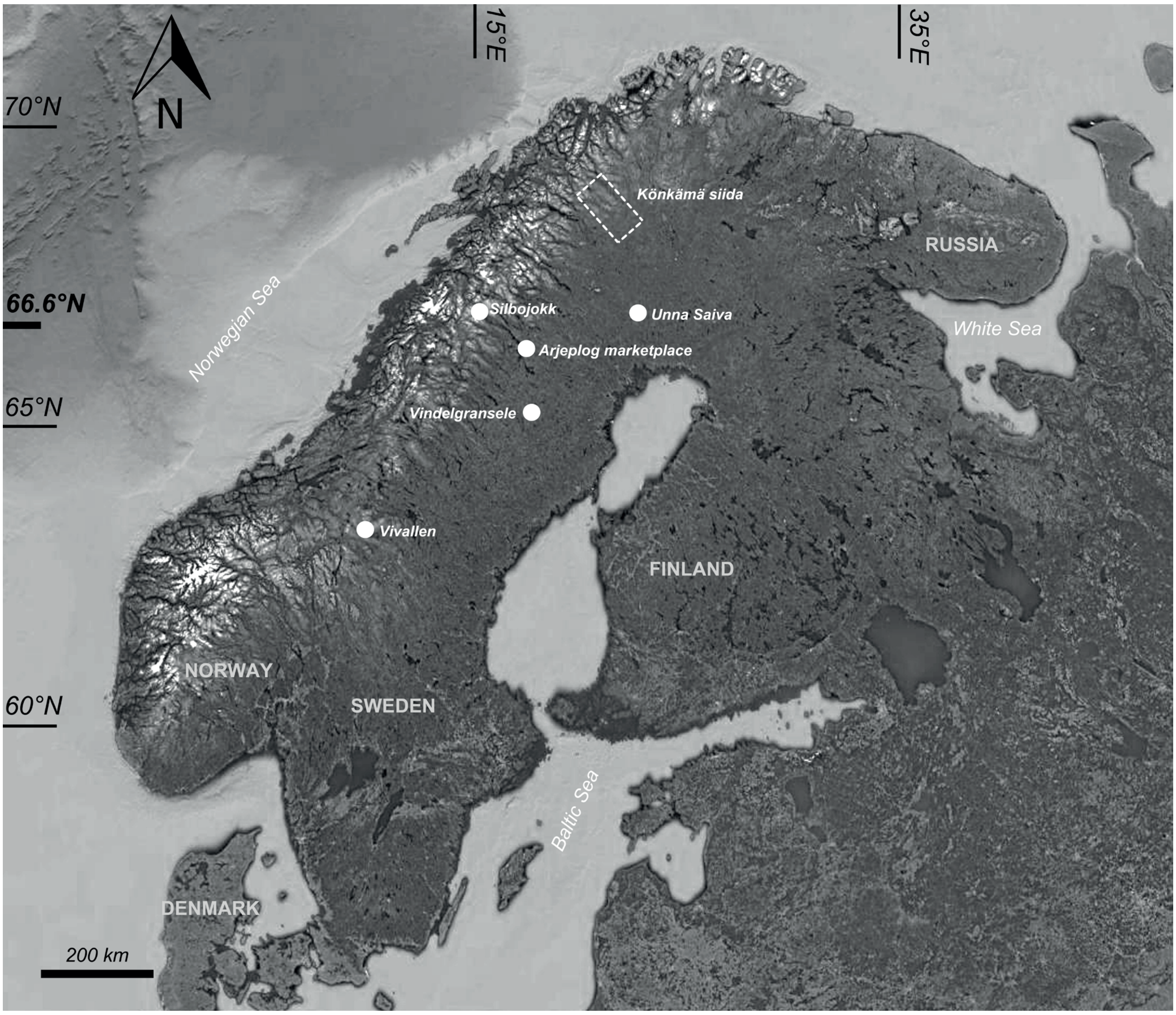

Figure 1. Map of the archaeological sites studied.

tion (Arell 1977; Karlsson 2006; Røed et al. 2011; Bjørnstad et al. 2012), although geographical differences in domestication must also be considered (Bergman et al. 2013; Hörnberg et al. 2015). The introduction of large-scale reindeer herding is a later process, and it probably occurred differently in forest Sámi and mountain Sámi economic contexts (Wallerström 2000; Marklund 2015).

Material

In this study, reindeer bones from one modern and five archaeological sites have been subject to stable isotope analysis: Vivallen, Vindelgransele, Arjeplog, Silbojokk, Unna Saiva and Könkämä siida (Fig. 1, Table 1). The sites range in date from the 11th to the 20th century and include offering sites, settlements and a marketplace. Bones from at least five distinct individual reindeer, all adult, were included from each site.

Vivallen is a burial site with an adjacent settlement in Tännäs parish in the province of Härjedalen. The Vivallen cemetery was excavated in the early 20th century by Hallström (1944), indicating that most of the interred individuals had been shrouded in birch bark, a typical feature of Sámi burial tradition. In the 1980s, a Swedish-Norwegian archaeo-osteological project investigated the dwelling site further. The site was situated along a pilgrimage route from Nidaros (present-day Trondheim) and is contextually dated to AD 1000–1300 (Hildebrandt 1988; Zachrisson 1997). Vivallen is today situated within the mountain Sámi village Ruvhten. The analysed reindeer bones derive from the settlement, in the area of a hearth and a heap of fire-cracked stone, and therefore interpreted as food leftovers (Hildebrandt 1986; Zachrisson 1997:117ff).

Vindelgransele is a Sámi offering site situated in a mountain Sámi area in the Sámi village Ran, Lyck-

Table 1. Overview of the sites and their contexts, dates and latitude. Shaded areas denote sites with potentially domesticated reindeer. VIV=Vivallen, VIN=Vindelgransele, ARJ=Arjeplog, SIL=Silbojokk, USA=Unna Saiva, KÖN=Könkämä

Site code	Site character	11th c.	12th c.	13th c.	14th c.	15th c.	16th c.	17th c.	18th c.	19th c.	20th c.	°N lat.
VIV	medieval settlement	×	×	×								62.5
VIN	offering site	×	×	×								65.0
ARJ	marketplace							×	×	×		66.0
SIL	mining settlement							×	×			66.5
USA	offering site				×	×	×	×				66.5
KÖN	modern settlement										×	68.0

sele parish, province of Lapland. The offering site was excavated by Hallström in 1941. Arrow heads, brooches and five stone sieidi were found in addition to marrow-split reindeer bones (Hallström 1941; Serning 1956:15; Manker 1957:234–235). According to the archaeological finds and context, the site can be dated from the late Viking Age to the Middle Ages (Hallström 1941).

A probable forest Sámi cot at Arjeplog's marketplace in the province of Lapland was excavated in 2011 by Lars Liedgren and Markus Fjellström (Liedgren 2012). The village of Arjeplog is situated between different mountain Sámi (Svaipa and Semisjaur-Njarg) and forest Sámi (Västra Kikkejaure and Mauskaure) communities. Coins found near the fireplace in the hut have dated the hut to between 1692 and 1820.

Silbojokk was a mining community with a smeltery for the exploitation of the silver mine in Nasafjäll between 1635 and 1659, situated in the area of the Semisjaur-Njarg mountain Sámi village, in Arjeplog parish in the province of Lapland. The settlement was excavated by the National Board of Antiquities in the 1980s, including a waste heap with 160 kg of unburnt faunal skeletal remains (Sten 1989:174–176). As the church activity in Silbojokk continued until 1777 and due to a second phase of mining, the reindeer bones analysed in this study can be dated contextually to the 17th and 18th centuries (Awebro et al. 1989).

The Sámi offering site of Unna Saiva is situated in the forest Sámi village of Gällivare, in the province of Lapland. Finds of a wide range of artefacts, from British coins to ring-formed buckles, were made. Reindeer bones from this site have been ^{14}C dated to between the 13th and 17th centuries (Salmi et al. 2015).

Modern reindeer bones from the Könkämä mountain Sámi village in Jukkasjärvi parish, Lapland, were also included in the study (Fjellström 2011; Dury et al. 2018). The carbon isotope values were corrected for the fossil fuel effect, by +1.6‰ (Marino & McElroy 1991).

Methods

Stable isotope analysis has been used for decades in archaeological studies on diet and mobility patterns (e.g. Sealy 2001). The stable carbon isotope value ($\delta^{13}C$) in different organisms is mainly determined by the photosynthetic pathway different plants use, which in turn depends on the climate from which the analysed material originates. The $\delta^{13}C$ value is expressed in relation to the standard VPDB (Vienna Pee Dee Belemnite) (Sealy 2001:270).

Stable nitrogen isotope values ($\delta^{15}N$) vary with trophic level in the food chain, as nitrogen fractionates c. 3–5‰ for each step up the food chain (Minagawa & Wada 1984; Bocherens & Drucker 2003), but also due to different biogeochemical or physiological factors, such as climate or starvation. The $\delta^{15}N$ value is expressed in relation to the standard AIR (Ambient inhalable reservoir) (Sealy 2001:272). Since lichens fix some of their nitrogen directly from the atmosphere, they exhibit lower nitrogen isotope values than other plants (Zielke et al. 2005). Also, with increasing precipitation and decreasing temperature, the nitrogen isotope composition of soil and plants decrease (Amundson et al. 2003). Hence, reindeer feeding mostly on lichen during the winter are expected to display low nitrogen isotopic values and high carbon isotopic values (Evans 2007:85; Britton 2009).

Stable sulphur isotope analysis is used to study mobility in both humans and animals. Sulphur enters the biological system through the soil and reflects the isotopic signature of the local bedrock. The sulphur isotope values ($\delta^{34}S$) can also vary due to atmospheric deposition and microbial processes. Hence, the sulphur isotopic values can be used to interpret local versus non-local individuals (Richards et al. 2003:37). The $\delta^{34}S$ values are expressed relative to the standard Vienna Canyon Diablo Troilite (VCDT) (Krouse 1980:436; Richards et al. 2003).

Collagen, the protein used in this study, was extracted from the reindeer bones according to the modified Longin method by Brown et al. (1988). For carbon and nitrogen isotope analysis, 0.4–0.6 mg and, for sulphur, 1.7–5.4 mg of collagen was weighed into tin capsules and then analysed at the Stable Isotope Laboratory (SIL), at the Department for Geological Sciences at Stockholm University, combusted in a CarloErba NC2500 elemental analyser connected to a mass spectrometer (continuous flow IRMS) – a Finnigan DeltaV advantage for $\delta^{13}C$ and $\delta^{15}N$ and a Finnigan Delta Plus for $\delta^{34}S$. The precision was ±0.15‰ or better for $\delta^{13}C$ and $\delta^{15}N$, and ±0.2‰ for $\delta^{34}S$.

We have used standard descriptive statistics to calculate mean and standard deviation (s.d.). Differences between mean values were tested in an analysis of variance with a post-hoc test of Least Square Deviation to test for significant differences. We also tested differences between standard deviations for the different groups in an F-test.

Results and discussion

The results of the stable isotope analysis are presented in Tables 2–5 and Figs. 2–5. In total, 33 out of 42 samples complied with the quality criteria for well-preserved collagen with regard to yield, carbon and nitrogen concentration and C/N ratio (DeNiro 1985; Ambrose 1990; van Klinken 1999). Of these, 30 also complied with the criteria for sulphur isotope analysis with regard to sulphur concentration, N/S and C/S ratios (Nehlich & Richards 2009).

Overall, the $\delta^{13}C$ values range from –22.0‰ to –17.7‰ (–19.1±0.9‰, mean±1 s.d.), the $\delta^{15}N$ values range from 1.1‰ to 8.5‰ (3.7±1.7‰, mean±s.d.) and the $\delta^{34}S$ values range from 8.7‰ to 13.1‰ (11.1±1.0‰, mean±s.d.). Summary statistics for each site are reported in Table 3. Two sites stand out, with the most extreme values: Arjeplog with the lowest $\delta^{13}C$ and $\delta^{34}S$ values and the highest $\delta^{15}N$ value, and Silbojokk with the highest $\delta^{13}C$ (together with Vivallen) and $\delta^{34}S$ values and the lowest $\delta^{15}N$ value.

The mean isotope values differ between sites, which is not unexpected (cf. Eriksson 2013). The isotopic ecology differs depending on altitude, humidity, temperature, etc. (e.g. Raich et al. 1997; Craine et al. 2009; Wang et al. 2015; 2019). However, it is not the absolute values, or their average, that is of main interest here, but the variation at each site. The variation provides information on whether or not all the reindeer come from a homogenous population, from one site, from a similar environment and/or have been herded in a similar way.

Lovell et al. (1986) suggested that the standard deviation for a population with homogenous diet would not exceed 0.3‰ for $\delta^{13}C$. This is in accordance with data for historical and modern caribou (wild reindeer) populations in North America, with standard deviations between 0.2‰ and 0.4‰ (Fig. 6) (Britton 2009; Drucker et al. 2010; McManus-Fry et al. 2018). This also fits very well with the s.d. for the modern settlement Könkämä (s.d.=0.3), and the offering sites (s.d. for both sites 0.4‰), indicating homogenous reindeer populations. In our statistical analyses of variation, we have combined the data from the two offering sites, although Unna Saiva is chronologically somewhat later than Vindelgransele. The marketplace Arjeplog (s.d.=1.3‰) and the medieval settlement Vivallen (s.d.=1.2‰) have substantially higher standard deviations, indicating non-homogenous reindeer populations, whereas the mining settlement Silbojokk (s.d.=0.5‰) is intermediate, but closer to being homogenous. The variation in $\delta^{13}C$ for the offering sites is statistically significantly lower than for the marketplace Arjeplog (p=0.001) and the medieval settlement Vivallen (p=0.006). The variation in $\delta^{13}C$ for the modern settlement Könkämä is also statistically significantly lower than for the marketplace Arjeplog (p=0.012) and the medieval settlement Vivallen (p=0.014). The mean $\delta^{13}C$ for Arjeplog (–19.9‰) is also statistically significantly lower than for Vivallen (–18.7‰, p=0.007) and the offering sites (–19.2‰, p=0.050).

The overall range of $\delta^{15}N$ values is wide, and the mean values differ significantly between the offering sites (5.0‰) on the one hand, and Vivallen (3.2‰, p=0.013), Silbojokk (1.9‰, p=0.000) and Könkämä (2.6‰, p=0.004) on the other. This indicates that the reindeer at the offering sites consumed considerably less lichen than those from the other sites, since lichens have significantly lower $\delta^{15}N$ values than, for example, grasses and willow (e.g. Morris et al. 2018; Shin et al. 2018; Marris et al. 2019; Tischler et al. 2019; Ohta & Saeki 2020). Lichens also have elevated $\delta^{13}C$ values compared to grasses and willow. The negative correlation between $\delta^{13}C$ and $\delta^{15}N$ in our data further supports this (R^2= 0.69, p<0.05). Taking a look at the variation in $\delta^{15}N$, the standard deviations for caribou populations in North America range between 0.2‰ and 0.8‰ (Fig. 6) (Britton 2009; Drucker et al. 2010; McManus-Fry et al. 2018). Compared with these, Arjeplog stands out as an exception, with a standard deviation of 2.8‰, which is statistically significantly different from all the other sites: Vivallen (s.d.=1.2‰, p=0.046), the offering sites (s.d.=0.7‰, p<0.001), Silbojokk (s.d.=0.6‰, p=0.005) and Könkämä (s.d.=0.6‰, p=0.004) (Table 5, Fig. 5). This accords

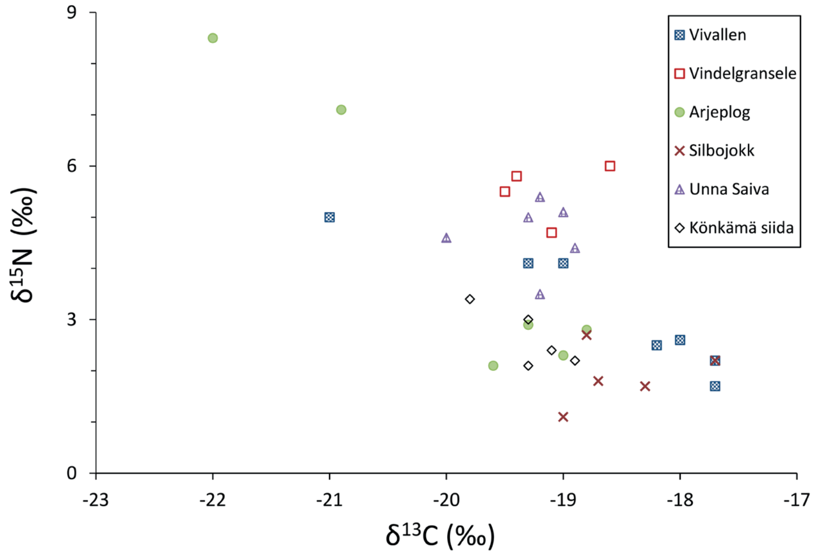

Figure 2. Stable carbon and nitrogen isotope data for the analysed reindeer.

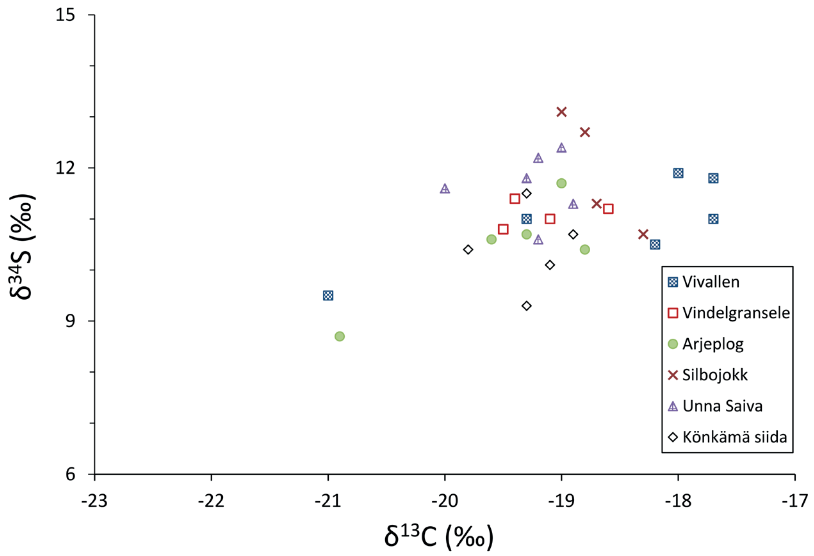

Figure 3. Stable carbon and sulphur isotope data for the analysed reindeer.

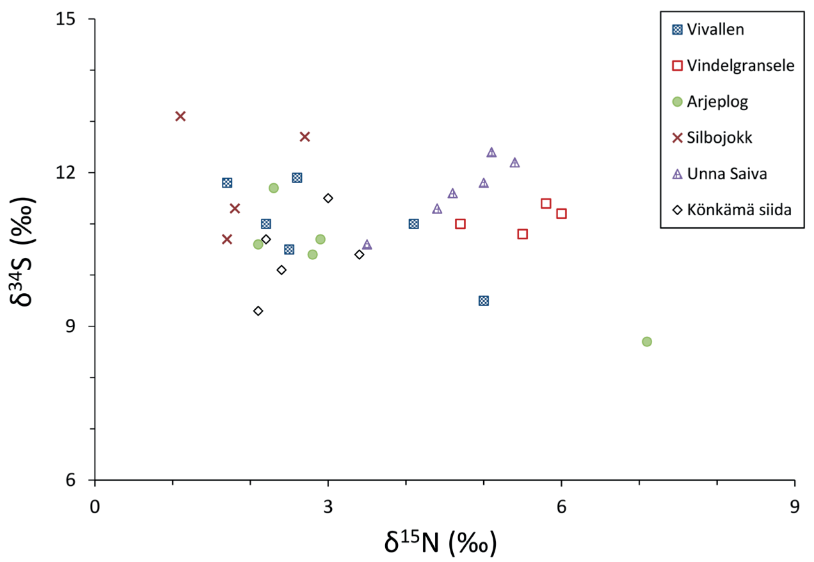

Figure 4. Stable nitrogen and sulphur isotope data for the analysed reindeer.

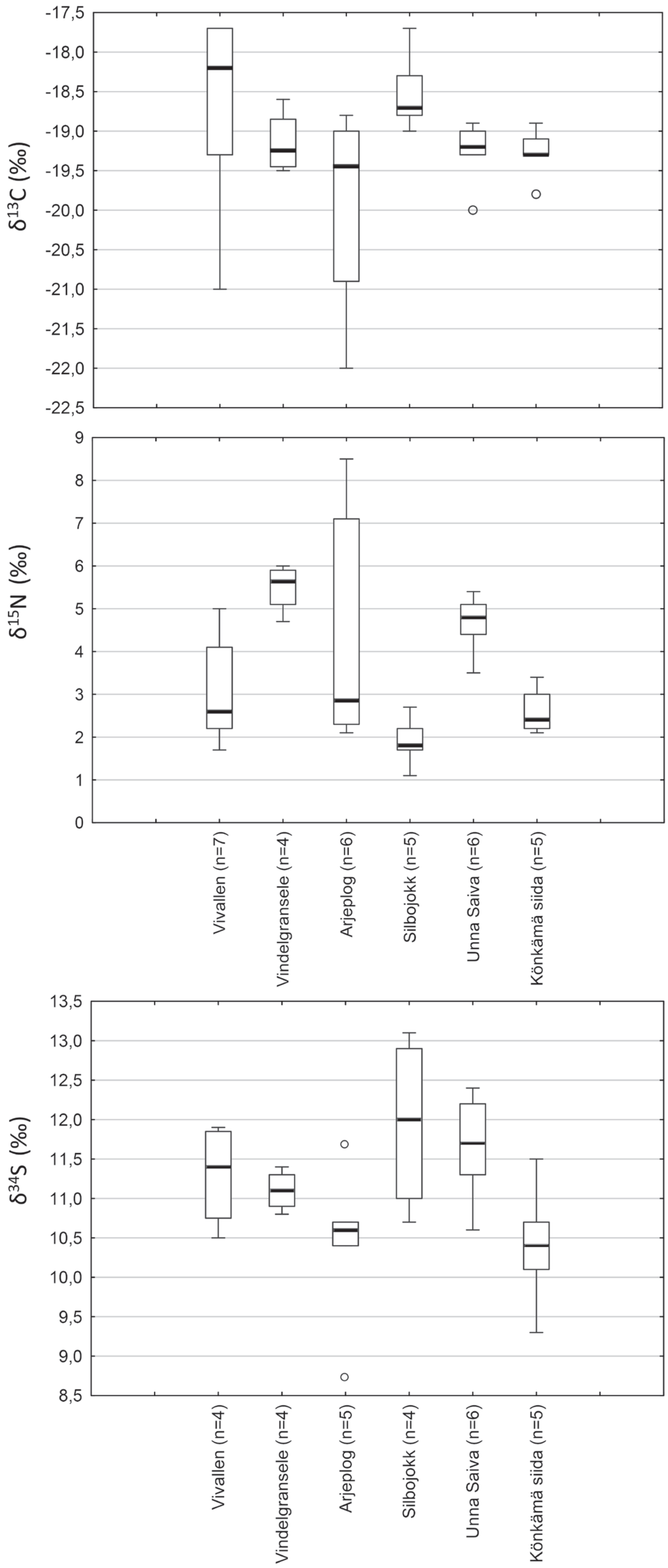

Figure 5. Boxplots of the stable carbon, nitrogen and sulphur isotope data for the analysed reindeer. Centre lines show the medians; box limits indicate the 25th and 75th percentiles; whiskers extend 1.5 times the interquartile range from the 25th and 75th percentiles, outliers are represented by circles.

Table 2. Stable isotope data for Vivallen (VIV), Vindelgransele (VIN), Arjeplog (ARJ), Silbojokk (SIL), Unna Saiva (USA) and Könkämä (KÖN). KÖN $\delta^{13}C$ values have been corrected for the fossil fuel effect by +1.6‰. Struck-out samples did not comply with the quality criteria and were excluded from statistics. References for previously published data: [1] Fjellström et al. ms a, [2] Fjellström et al. ms b, [3] Salmi et al. 2015, [4] Dury et al. 2018.

Sample code	Skeletal element	Collagen yield (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	% C	% N	% S	C/N	C/S	N/S	Data from
VIV 1	Phalanx	1.8	–17.7	2.2	11.0	41.9	14.8	-	3.3	-	-	[1]
VIV 2	Long bone	1.3	–21.0	5.0	9.5	42.4	14.7	-	3.4	-	-	[1]
VIV 3	Long bone	1.1	–19.0	4.1	-	41.4	14.5	-	3.3	-	-	[1]
VIV 4	Long bone	5.2	–19.3	4.1	11.0	43.8	14.4	0.18	3.5	650	214	[1]
VIV 5	Long bone	5.2	–18.2	2.5	10.5	43.9	15.2	0.23	3.4	509	177	[1]
VIV 18	Mandible	4.1	–17.7	1.7	11.8	41.0	14.5	0.18	3.3	608	215	[1]
VIV15	Long bone	5.0	–18.0	2.6	11.9	41.2	14.6	0.22	3.3	500	177	[1]
VIN 1	Long bone	3.4	–19.4	5.8	11.4	43.8	15.2	0.28	3.4	417	145	this study
VIN 3	Long bone	4.2	–19.1	4.7	11.0	43.6	15.2	0.26	3.4	448	156	this study
VIN 4	Long bone	5.4	–19.5	5.5	10.8	42.9	15.0	0.29	3.4	395	138	this study
VIN 6	Long bone	5.5	–18.6	6.0	11.2	43.1	15.3	0.26	3.3	443	157	this study
ARJ 1	Phalanx	11.5	–21.7	2.6	11.0	44.0	13.1	0.15	3.9	783	233	this study
ARJ 2	Scapula	5.2	–21.5	2.2	11.4	43.8	12.3	0.15	4.2	780	219	this study
ARJ 3	Pars petrosa	1.2	–22.0	8.5	-	41.6	13.7	-	3.6	-	-	this study
ARJ 4	Mandible	8.8	–18.8	2.8	10.4	45.2	16.3	0.18	3.2	670	242	this study
ARJ 5	Humerus	7.1	–19.0	2.3	11.7	44.6	16.3	0.21	3.2	567	207	this study
ARJ 6	Vertebra	5.9	–20.9	7.1	8.7	43.7	15.7	0.19	3.2	613	220	this study
ARJ 8	Os coxae	6.6	–21.6	3.9	10.5	43.5	12.4	0.13	4.1	893	254	this study
ARJ 9	Cranium	2.4	–19.6	2.1	10.6	41.8	15.0	0.19	3.3	587	210	this study
ARJ 10	Os coxae	6.3	–19.3	2.9	10.7	40.7	15.0	0.18	3.2	604	223	this study
SIL 1	Tibia dx	10.5	–21.3	2.4	8.8	41.1	10.7	0.18	4.5	609	158	[2]
SIL 2	Tibia dx	2.4	–17.7	2.2	-	40.8	14.4	-	3.3	-	-	[2]
SIL 3	Tibia dx	6.3	–18.3	1.7	10.7	42.4	15.0	0.26	3.3	435	154	[2]
SIL 4	Tibia dx	6.6	–19.0	1.1	13.1	42.8	15.0	0.27	3.3	423	148	[2]
SIL 5	Tibia dx	7.2	–18.7	1.8	11.3	42.2	15.0	0.26	3.3	433	154	[2]
SIL 6	Tibia dx	4.9	–18.8	2.7	12.7	37.1	13.1	0.22	3.3	450	159	[2]
USA 1	Mandible dx	7.2	–19	5.1	12.4	43.1	15.1	0.25	3.3	460	161	[3]
USA 2	Mandible dx	3.3	–19.2	3.5	10.6	40.9	14.4	0.25	3.3	437	154	[3]
USA 3	Mandible dx	nd	–20	4.6	11.6	43.2	15.3	0.27	3.3	427	151	[3]
USA 4	Mandible dx	4.4	–18.9	4.4	11.3	44.1	14.5	0.26	3.6	453	149	[3]
USA 5	Mandible dx	5.3	–19.2	5.4	12.2	43.8	15.5	0.24	3.3	487	172	[3]
USA 6	Mandible dx	4.1	–19.3	5.0	11.8	43.7	15.7	0.25	3.2	467	168	[3]
KÖN 1	Mandible sn	8.6	–18.9	2.2	10.7	44.9	16.5	0.27	3.2	444	139	[4]
KÖN 2	Mandible sn	9.1	–19.3	2.1	9.3	43.4	15.0	0.30	3.4	193	163	[4]
KÖN 3	Mandible sn	10.5	–19.8	3.4	10.4	47.0	15.6	0.27	3.5	232	133	[4]
KÖN 4	Mandible sn	12.2	–19.3	3.0	11.5	45.6	16.0	0.25	3.3	243	154	[4]
KÖN 5	Mandible sn	9.2	–19.1	2.4	10.1	44.9	15.7	0.28	3.3	214	170	[4]

Table 3. Mean ± 1 standard deviation of stable isotope data for the analysed reindeer. Number of samples (n) for $\delta^{13}C$/$\delta^{15}N$ (n for $\delta^{34}S$ in brackets, if different).

Site	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
Vivallen	7 (6)	–18.7±1.2	3.2±1.2	11.0±0.9
Vindelgransele	4	–19.2±0.4	5.5±0.6	11.1±0.3
Arjeplog	6 (5)	–19.9±1.3	4.3±2.8	10.4±1.1
Silbojokk	5 (4)	–18.5±0.5	1.9±0.6	12.0±1.1
Unna Saiva	6	–19.3±0.4	4.7±0.7	11.7±0.7
Könkämä siida	5	–19.3±0.3	2.6±0.6	10.4±0.8

with its function as a marketplace, with reindeer brought in from different areas for consumption. Although not as high as for Arjeplog, Vivallen also has a high standard deviation, which could be a result of its location along the pilgrimage route.

The $\delta^{34}S$ values vary according to geology, which means that reindeer that graze on the same pasture will have similar $\delta^{34}S$ values. Although the overall range is rather small (8.7–13.1‰), there are statistically significant differences between the mean $\delta^{34}S$

Table 4. Statistically significant differences ($p<0.05$) in mean isotopic values between different contexts. VIV=Vivallen, VIN=Vindelgransele, USA=Unna Saiva, ARJ=Arjeplog, SIL=Silbojokk, KÖN=Könkämä, C=$\delta^{13}C$, N=$\delta^{15}N$, S=$\delta^{34}S$.

Site	Medieval settlement (VIV)	Offering sites (VIN+USA)	Marketplace (ARJ)	Mining settlement (SIL)	Modern settlement (KÖN)
VIV	-	N	C	-	-
VIN+USA	N	-	CS	N	NS
ARJ	C	CS	-	NS	-
SIL	-	N	NS	-	S
KÖN	-	NS	-	S	-

Table 5. Statistically significant differences ($p<0.05$) in isotopic variation between different contexts. VIV=Vivallen, VIN=Vindelgransele, USA=Unna Saiva, ARJ=Arjeplog, SIL=Silbojokk, KÖN=Könkämä, C=$\delta^{13}C$, N=$\delta^{15}N$, S=$\delta^{34}S$.

Site	Medieval settlement (VIV)	Offering sites (VIN+USA)	Marketplace (ARJ)	Mining settlement (SIL)	Modern settlement (KÖN)
VIV	-	C	N	-	C
VIN+USA	C	-	CNS	S	-
ARJ	N	CNS	-	N	CN
SIL	-	S	N	-	-
KÖN	C	-	CN	-	-

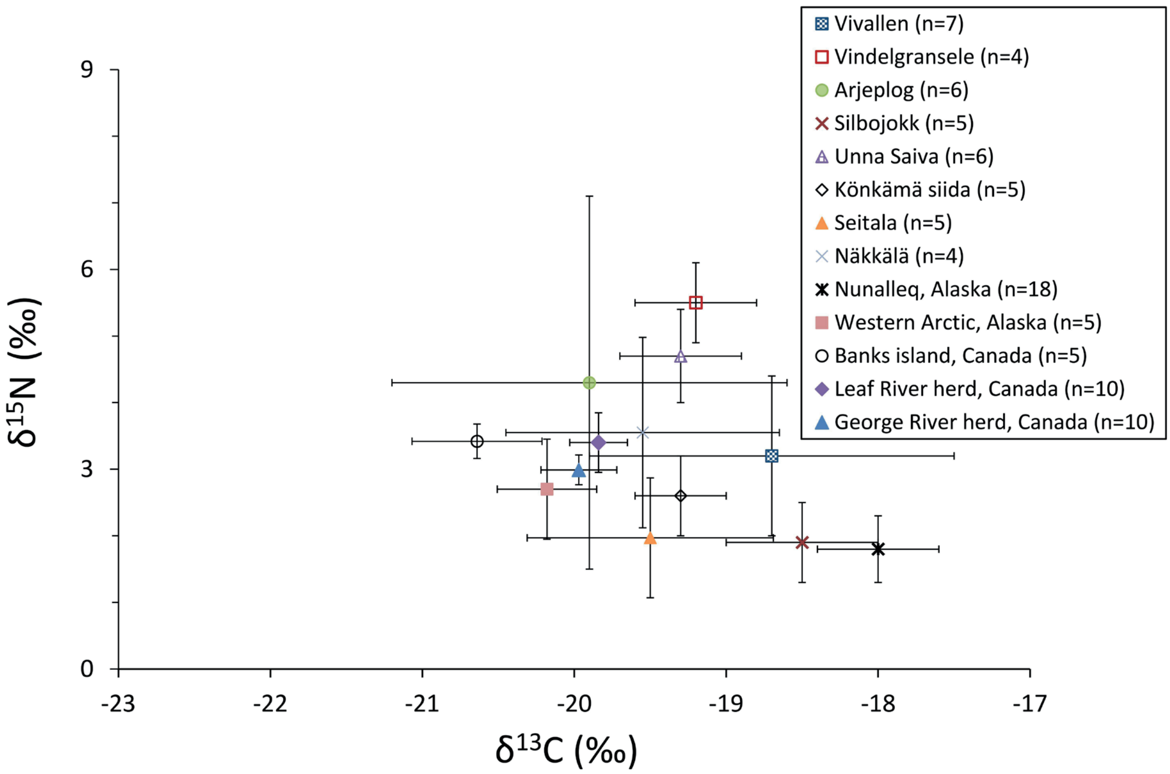

Figure 6. Mean and standard deviations for bone collagen $\delta^{13}C$ and $\delta^{15}N$ values from the analysed reindeer in this study, from reindeer at two Finnish offering sites and from caribou in North America. Data from this study and Britton 2009; Drucker et al. 2010; McManus-Fry et al. 2018; Núñez et al. in press.

values of the sites, thus demonstrating the different grazing areas for the different groups. Variation in $\delta^{34}S$ is statistically significantly lower for the offering sites (s.d.=0.6‰) than for Arjeplog (s.d.=1.1‰, p=0.050) and Silbojokk (s.d.=1.1‰, p=0.044).

Per Ramqvist (2012:37) has suggested that the metal offering sites in northernmost Sweden were situated on the border between different regions. This would imply that they were used by more than one group of people. At sacrificial sites, a multitude of depositions could be made, including tobacco, alcohol, metal objects, reindeer, blood and various foodstuffs. These offerings were made partly to ensure good luck in the hunt, to please the gods, and in time of crisis and/or sicknesses. Offering sites were generally situated close to herding and slaughter areas, as well as migration routes, and close to hunting pits in the case of wild reindeer hunting. Offerings were also made in connection with the living area, in and around the hut (Mebius 2003:133ff; Äikäs 2015). The location in a border zone is supported by stable isotope data for reindeer from two Finnish offering sites, Seitala and Näkkälä, where the variation in both $\delta^{13}C$ and $\delta^{15}N$ values (Fig. 6) implies that the sacrificed reindeer derive from more than one herd (Seitala $\delta^{13}C$ s.d. 0.8‰, Näkkälä s.d. 0.9‰, Núñez et al. in press).

By contrast, the offering sites Vindelgransele and Unna Saiva are highly homogenous in carbon, nitrogen and sulphur isotope values, indicating that the reindeer at each site came from one herd, and thus, by implication, that these sites were each used by a single group of people. The elevated $\delta^{15}N$ values compared to the other sites, and also compared to North American caribou, suggest that the reindeer at the offering sites consumed considerably less lichen, since lichen have very low $\delta^{15}N$ values. This in turn indicates that they were foddered during winter, as previously suggested by Salmi et al. (2015). The Könkämä reindeer, although domesticated, were free-ranging and not fed by people; thus, they have low nitrogen isotope values.

Among the settlement sites, the mountain Sámi settlement Könkämä can be used as a point of reference for migratory free-ranging domesticated reindeer. In the same way as the North American caribou, the variation is low in all three isotopes in Könkämä.

At Vivallen, the oldest site, possibly predating the domestication of reindeer, variation is higher, suggesting a heterogenous population of reindeer. Maybe the wide range of isotopic values bear witness to trade, just like the coins found at the site; this wide range is also compliant with the location along a pilgrimage route. One of the reindeer from Vivallen has much lower carbon, and higher nitrogen isotope values than the rest from this site, which suggests foddering. If this was before domestication, this reindeer could have been kept, for example, as a means of transportation or used as a decoy in the hunt for wild reindeer (Ingold 1980; Fjellström 1985).

The third settlement, Silbojokk, deviates from the others, being a mining community, with a human population of workers running the smeltery and the mine in Nasafjäll. These people originated from different geographical areas and had differing cultural preferences with regard to food. All food was brought into the site from the surrounding area, e.g., Arjeplog. The variation in $\delta^{34}S$ values likely reflects that the reindeer derive from more than one homogenous population. Arjeplog's marketplace and the Silbojokk mining community are archaeologically dated to the same period and in some part to the same historic event: the exploitation and transport of silver using reindeers from Silbojokk to Piteå and Skellefteå passing through Arjeplog during the 17th and 18th centuries (Bergman et al. 2014).

The marketplace Arjeplog is very heterogenous in carbon, nitrogen and sulphur, and also has some of the most extreme values. Considering the character of the site, this is not surprising. A marketplace is a place for both trade and social exchange, hence the reindeer from the marketplace in Arjeplog perhaps represent different Sámi economies. Historically, there is evidence of trade between forest and mountain Sámi (Marklund 2015:60). The marketplace in Arjeplog can also be linked to the mining activities in Silbojokk. When the silver from Nasafjäll was transported to the coast, it passed through the village of Arjeplog, and it is very likely that different merchandise was exchanged both between different Sámi communities and with other north Scandinavian groups.

Conclusion

In conclusion, the analysis of reindeer from northern Sweden has demonstrated that stable isotope analysis is a useful tool to identify different practices in the utilization of reindeer. We have further suggested that low $\delta^{13}C$ in tandem with high $\delta^{15}N$ values indicate foddering. We propose that the high $\delta^{15}N$ values at the offering sites Vindelgransele and Unna Saiva, as well as at the settlement Vivallen, were related to foddering. The analysis further indicates that the offering sites were used by single groups, as indicated by the low variation in isotope values. An important outcome of our study is that the biology of reindeer in Sápmi was culturally influenced by the Sámi even before the reindeer was domesticated, as suggested by a single reindeer at Vivallen which probably had been foddered.

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